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CERTAIN EVOLUTIONARY ASPECTS OF HUMAN MORTALITY RATES¹

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I

It is the purpose of this paper to set forth some facts regarding human mortality which appear to lead with great clarity to certain evolutionary generalizations of interest to the biologist, which have hitherto been overlooked so far as I am aware. The present fashion in the study of evolution is towards the analytical discussion of the factors. Synthetic general discussions of broad phases of organic evolution, which occupied so prominent a place in early post-Darwinian times, are now but rarely found in biological literature. This may fairly be regarded as a blessing, but perhaps not an entirely unmitigated one. While much of the general discussion of evolution of the period of fifty years ago was utter nonsense, still a view of some of the aspects of the forest may be at least occasionally stimulating, and particularly in these present days when we are accumulating such a mass of precise data about the characteristics of the trees.

It is in some ways remarkable that so little thought and interest have been given by general biologists to the phases of biology which form the working material of that branch of applied science which is roughly but still sufficiently intelligibly labelled “vital statistics.” The data

¹ Papers from the Department of Biometry and Vital Statistics, School of Hygiene and Public Health, Johns Hopkins University, No. 7.

In preparing this paper I have had the benefit in matters of pathological anatomy and embryology of the critical acumen and wide knowledge of my colleague, Dr. W. T. Howard, to whom I am greatly indebted for this help.

of human natality, morbidity and mortality, when intelligently and broadly studied, can, I am sure, throw a great deal of light on some of the deepest and most significant problems of general biology. If the facts presented in this paper succeed in some small degree in demonstrating that this opinion is not an entirely idle one, the purpose of this particular piece of work will have been served.

II

By an international agreement among statisticians the causes of human mortality are, for statistical purposes, rather rigidly defined and separated into something over 180 distinct causes. It should be clearly understood that this convention is distinctly and essentially statistical in its nature. In recording the statistics of death the vital statistician is confronted with the absolute necessity of putting every death record into some category or other in respect of its causation. However complex biologically may have been the train of events leading up to a particular demise, the statistician must record the terminal "cause of death" as some particular thing. The International Classification of the Causes of Death is a code which is the result of many years' experience and thought. Great as are its defects in certain particulars, it nevertheless has certain marked advantages, the most conspicuous of which is that by its use the vital statistics of different countries are put upon a uniform basis.

The several separate causes of death are grouped in the International Classification into the following general classes:

- I. General diseases.
- II. Diseases of the nervous system and of the organs of special sense.
- III. Diseases of the circulatory system.
- IV. Diseases of the respiratory system.
- V. Diseases of the digestive system.
- VI. Non-venereal diseases of the genito-urinary system and annexa.

- VII. The puerperal state.
- VIII. Diseases of the skin and of the cellular tissue.
- IX. Diseases of the bones and of the organs of locomotion.
- X. Malformations.
- XI. Early infancy.
- XII. Old age.
- XIII. External causes.
- XIV. Ill-defined diseases.

It is evident enough that this is not primarily a biological classification. The first group, for example, called "General diseases," which caused in 1916, in the Registration Area of the United States approximately one fourth of all the deaths, is a curious biological and clinical melange. It includes such diverse entities as measles, malaria, tetanus, tuberculosis, cancer, gonococcal infection, alcoholism, goiter, and many other equally unlike causes of death. For the purposes of the statistical registrar it has useful points to make this "General diseases" grouping, but it clearly corresponds to nothing natural in the biological world. Again, in such part of the scheme as does have some biological basis, the basis is different in different rubrics. Some of the rubrics have an organological base, while others, as "Malformations" have a causational rather than an organological base.

Altogether it is evident that if any synthetic biological use is to be made of mortality data a fundamentally different scheme of classification of the causes of death will have to be worked out.

III

For the purposes of this study² I have developed an

² It should be clearly understood that this phrase "For the purposes of this study" means precisely what it says. I am not advocating a new classification of the causes of death for statistical use. I should oppose vigorously any attempt to substitute a new classification (mine or any other) for the International List now in use. Uniformity in statistical classification is essential to usable, practical vital statistics. Such uniformity has now become well established through the International Classification. It would be most

entirely different general classification of the causes of death on a reasonably consistent biological basis. The underlying idea of this new classification is to group all causes of death under the heads of the several organ systems of the body, the functional breakdown of which is the immediate or predominant cause of the cessation of life. All except a few of the statistically recognized causes of death in the International Classification can be assigned places in such a biologically grouped list. It has a sound logical foundation in the fact that, biologically considered, death results because some organ system, or group of organ systems, fails to continue its function. Practically, the plan involves the reassignment of all of the several causes of death now grouped by vital statisticians under heading "I. General diseases." It also involves the re-distributing of causes of death now listed under the puerperal state, malformations, early infancy, and certain of those under external causes.

The headings finally decided upon for the new classification are as follows:

- I. Circulatory system, blood, and blood-forming organs.
- II. Respiratory system.
- III. Primary and secondary sex organs.
- IV. Kidneys and related excretory organs.
- V. Skeletal and muscular systems.
- VI. Alimentary tract and associated organs concerned in metabolism.
- VII. Nervous system and sense organs.
- VIII. Skin.
- IX. Endocrinial system.
- X. All other causes of death.

It should be emphasized before presenting the tables

undesirable to make any radical changes in the Classification now. I have in this paper made a rearrangement of the causes of death, for the purposes of a specific biological problem, and no other. I am not "proposing a new classification of vital statistics" for official or any other use except the one to which I here put it.

of detailed statistics on this new classification that the underlying idea of this rearrangement of the causes of death is to put all those lethal entities together which bring about death because of the functional organic breakdown of the same general organ system. The cause of this functional breakdown may be anything whatever in the range of pathology. It may be due to bacterial infection; it may be due to trophic disturbances; it may be due to mechanical disturbances which prevent the continuation of normal function; or to any other cause whatsoever. In other words, the basis of the present classification is not that of pathological causation, but it is rather that of organological breakdown. We are now looking at the question of death from the standpoint of the pure biologist, who concerns himself not with what causes a cessation of function, but rather with what part of the organism ceases to function, and therefore causes death. It is to be hoped that the novelty of this method of looking at the causes of human mortality will not *per se* prejudice the reader against it, to the degree at least of preventing him from examining the detailed results and consequences of such classification, which will be presented in what follows.

There will now be presented in a series of tables the statistical data as to deaths arranged in this classification. The data given are in the form of death rates per hundred thousand living at all ages from various causes of death, arranged by organ systems primarily concerned in death from the specified disease. The statistics presented are from three widely separated localities and times, viz., (a) from the Registration Area of the United States; (b) from England and Wales; and (c) from the City of Sao Paulo, Brazil. The first two columns of each table give the death rates, arranged in descending order of magnitude in the first column, for the Registration Area of the United States for the two periods, 1906-10 and 1901-05. The third column of each table gives the death rate from the same cause of death for England and

Wales in the year 1914. The fourth column gives the rates for Sao Paulo for the year 1917. The data for the United States Registration Area were extracted from the volume of Mortality Statistics for 1916, issued by the Bureau of the Census. The English data were extracted from the Report of the Registrar General of England and Wales for 1914. The Sao Paulo rates were calculated from data as to deaths and population given in the "Annuario Demographico" of Sao Paulo for 1917.

TABLE I
CIRCULATORY SYSTEM, BLOOD AND BLOOD-FORMING ORGANS

No. ³	"Cause of Death" as per International Classification	Registration Area, U.S.A.		England and Wales 1914	Sao Paulo 1917
		1906-10	1901-05		
79	Organic diseases of the heart.....	133.2	124.2	137.3	130.0
81	Diseases of the arteries.....	17.7	9.4	23.5	59.7
78	Acute endocarditis.....	12.2	11.2	5.1	6.5
7	Scarlet fever.....	10.6	11.0	7.7	5.4
150 ⁴	Congenital malformation of the heart.....	9.0	6.7	4.2	4.6 ⁵
80	Angina pectoris.....	6.8	6.6	3.2	2.2
82	Embolism and thrombosis.....	3.9	4.2	8.9	8.3
20	Purulent infection and septicemia.....	3.8	6.1	1.8	22.2
142	Gangrene.....	3.5	4.5	4.4	2.6
4	Malaria.....	2.6	4.8	0.2	2.8
85	Hemorrhage and other diseases of the circulatory system.....	1.6	2.8	0.6	2.4
53	Leukemia.....	1.5	1.2	2.0	2.0
77	Pericarditis.....	1.3	2.1	1.2	1.1
54	Anemia, chlorosis.....	1.0	0.5	6.4	3.7
83	Diseases of the veins.....	0.6	0.6	1.0	0.7
84	Diseases of the lymphatics.....	0.3	0.2	0.9	0.2
116	Diseases of the spleen.....	0.2	0.3	0.2	0.4
16	Yellow fever.....	0	0.3	0	0
15	Plague.....	0	0.1	0	0
2	Typhus fever.....	6	6	0	0
3	Relapsing fever.....	6	6	0	0
11	Miliary fever.....	6	6	0	0
Totals.....		209.8	196.8	208.6	254.8

Nine of the items in Table I, namely items 77 to 85 inclusive, are those of rubric III of the International Class-

³ The numbers in this column in this and the following tables are the numbers of the several causes of death in the International Classification.

⁴ In part.

⁵ The Sao Paulo statistics do not separate congenital malformations. This is the total rate.

⁶ Less than 0.1 per 100,000.

ification, "Diseases of the circulatory system." The other items of Table I require some special explanation.

No. 7, "Scarlet fever," appears in the International Classification under "General diseases." It is placed here in the organological classification because in the vast majority of cases of fatal scarlet fever it is the clinical form of the disease known as septic scarlatina which is responsible for the death. Spengarn⁷ says that "septic scarlatina is responsible for most of the deaths." "The general condition is one of septicemia." It, therefore, seems best, on the present plan of biological classification, to put scarlet fever with the circulatory system, blood and blood-forming organs, since septicemia is the result of a breakdown and failure to function of the normal defensive serologic mechanism of the body.

The item 150 in the International Classification is entitled "Congenital malformations," and there includes the following three subdivisions: Hydrocephalus, congenital malformations of the heart, and other congenital malformations. The second of these subdivisions, "congenital malformations of the heart," obviously belongs here, and is consequently included, while the other subdivisions do not.

Item 20, "Purulent infection and septicemia," is taken from "General Diseases" and put here on the same reasoning as that just stated for scarlet fever.

Item 142, "Gangrene," is placed here because normally in civilian life, under the conditions which prevailed when these statistics were taken, most fatal gangrene is due to impairment of the circulation as a primary cause. The arteries become occluded either from endarterial inflammation, due either to frank infection, or to various somewhat obscure causes producing local obliterative arteriosclerosis, or to trauma, or to thrombosis or embolism, especially in association with cardiac disease. Again some cases of gangrene, in the sense under con-

⁷ Spengarn, A., article "Scarlatina," in Ref. Handbook Med. Sci., Vol. VII, p. 658, 1916.

sideration here, are doubtless due to extensive phlebitis and primary thrombosis of veins. In any case it is a part of the circulatory system which breaks down, and therefore we are warranted in placing this disease in Table I.

Item 4, "Malaria," is fundamentally a disease of the blood, and hence is placed here from "General diseases."

All the evidence that the pathological anatomist has leads to the view that yellow fever, typhus fever, relapsing fever and miliary fever are blood diseases. They have the lesions of septicemias, or are transmitted by biting insects, or both.

Items 53 and 54, "Leukemia" and "Anemia, chlorosis," represent breakdowns of the blood or blood-forming organs of the body. They are taken from Class I of the International Classification.

In the International Classification item 116, "Diseases of the spleen," is placed under the general rubric of "Diseases of the digestive system." This is a good illustration of the biological absurdities which appear in the statistical classification now used. Just what the spleen has to do directly with digestion does not appear. It is primarily a blood-forming organ.

Bubonic plague is a disease of the lymphatic system. The great epidemics of fatal type are characterized by the pneumonic and septicemic forms. On the whole, it seems best to place this disease here.

It is evident from the data of Table I that where death ensues from a breakdown of any part of the circulatory or blood systems it is preponderantly the heart itself which is at fault. Diseases of the arteries, which, generally speaking, mean arteriosclerosis, come second in importance. The other causes listed are of relatively minor importance. The relatively enormous rates for diseases of the arteries and for purulent infection and septicemia in São Paulo are noteworthy.

For the present no attempt will be made to discuss the reasons for these differences, since the main object in this

section of the paper is to get the data as a whole before the reader.

The question may fairly be raised as to whether item 22, "Anthrax," should not come in Table I with the blood rather than with the skin in Table VIII. It is a difficult question and one not capable of any absolutely precise solution in the nature of the case. Most fatal cases of anthrax, if not all, are septicemias, or, perhaps better, bacteremias, due finally to failure of the defensive mechanism of the blood. Furthermore, pneumonic and intestinal forms of anthrax occur. On the whole, however, the weight of evidence seems to be that in the majority of cases at least the organism gains its entrance and first victory through the skin, and that the biological strength or weakness of that organ system determines primarily what will subsequently happen. Fortunately, the total rate from anthrax is so small as to be of no significance in any general result.

The causes of death listed in Table II include all of

TABLE II
RESPIRATORY SYSTEM

No.	"Cause of Death" as per International Classification	Registration Area, U. S. A.		England and Wales 1914	Sao Paulo 1917
		1906-10	1901-05		
28&29	Tuberculosis of lungs (including acute miliary tuberculosis).....	146.8	170.7	104.5	119.8
92	Pneumonia (lobar and undefined).....	103.0	125.5	57.5	59.9
91	Bronchopneumonia.....	40.4	32.9	50.9	103.9
9	Diphtheria and croup.....	22.4	29.6	16.0	9.6
10	Influenza.....	16.4	19.9	16.1	16.1
89	Acute bronchitis.....	15.2	21.4	108.7 ⁸	62.1
8	Whooping cough.....	11.5	10.9	21.8	9.1
90	Chronic bronchitis.....	11.1	15.4	3.9
6	Measles.....	10.8	9.0	24.7	1.5
94	Pulmonary congestion and apoplexy.....	5.6	8.6	4.5	9.4
93	Pleurisy.....	4.1	4.9	4.0	7.6
96	Asthma.....	2.9	3.7	4.9	2.8
98	Other respiratory diseases.....	2.8	4.3	1.7	5.2
87	Diseases of the larynx.....	1.7	2.3	3.2	0.9
97	Pulmonary emphysema.....	0.4	0.7	1.2	2.2
95	Gangrene of the lungs.....	0.4	0.5	0.3	3.3
86	Diseases of the nasal fossae.....	0.2	0.2	0.2	0.2
Totals.....		395.7	460.5	420.2	417.5

⁸ Includes acute and chronic bronchitis.

those under the general heading IV, "Diseases of the respiratory system" of the International Classification, with a single exception, namely No. 88, "Diseases of the thyroid body," which goes elsewhere in the present classification. In addition, there are in Table II four causes of death which are not included with the respiratory system in the International List. These four we may consider in detail.

Item 28, "Tuberculosis of lungs," obviously belongs with the respiratory system, in a strictly organological classification. The breakdown of the lungs as a functioning system is the biological meaning of death from pulmonary tuberculosis. This item is taken from rubric I, "General diseases," of the International Classification. Acute miliary tuberculosis has been included with pulmonary tuberculosis here, rather than as a separate item, for the reason that the English statistics treat these items together. No significant error is introduced by this procedure for two reasons: (a) the rate from miliary tuberculosis by itself is very small; and (b) probably a majority of cases of acute miliary tuberculosis have the lungs as the chief organ affected.

Item 9, "Diphtheria and croup," is again obviously a respiratory category, on the basis of organs affected. It does not seem to me to be to the point to argue that death in diphtheria is in many cases due to a general toxemia. To do so brings into prominence an aspect of the matter foreign to our present point of view. The infecting agent attacks a part of the respiratory system. If that system were in man as in the insects, lined with chitin in considerable part, presumably death from the clinical entity known as diphtheria would never occur, because the organism would not get the necessary foothold to produce enough toxin to be troublesome. It seems to me further that there is a fundamental biological difference between the cases of scarlet fever and septicemia on the one hand, and diphtheria on the other hand, which leads to the placing of the former with the blood and the latter

with the respiratory system. It is apparent, of course, that the matter of the placing of diphtheria can be argued from both sides, but on the whole I incline to the view that it belongs here with the respiratory organs rather than with the blood.

Item 10, "Influenza," is so obviously respiratory as to require no discussion. The same may be said of item 8, "Whooping cough."

The reason for including item 6, "Measles," here is clearly stated by Spengarn⁹ when he says regarding measles: "The mortality of this disease is largely due to the pulmonary complications," and further: "The high mortality among the measles patients in children's hospitals is attributed to bronchopneumonia."

Table II brings out very clearly one important point in favor of the present classification. It is evident from an examination of the four columns of rates that the usages in respect of the diagnostic terminology of respiratory affection, especially the pneumonias and bronchitis, differ greatly in these three countries. Yet the *totals* for all respiratory system deaths are closely similar for all three countries and periods. In other words, the organological totals get rid to a large degree of one of the greatest sources of error in vital statistics, the varying terminology of disease in different regions.

The first and the fourth items in Table III present a new angle of the problem of the classification of the causes of death which needs particular discussion. These items, "Premature birth" and "Injuries at birth" represent a part of the items 151 and 152 of the International Classification. In the International Classification, item 151, which comes under the general heading "XI. Early infancy," has this general title "Congenital debility, icterus and sclerema (total)." This contains two separate subdivisions not numbered, the first being "Premature birth," and the second "Congenital debility,

⁹ Spengarn, A., article "Measles" in Ref. Handbook Med. Sci., Vol. VI, p. 283, 1916.

TABLE III
PRIMARY AND SECONDARY SEX ORGANS

No.	"Cause of Death" as per International Classification	Registration Area, U. S. A.		England and Wales 1914	São Paulo 1917
		1906-10	1901-05		
151 ¹¹	Premature birth.....	35.7	30.8	46.9	66.8
42	Cancer of the female genital organs.....	10.8	10.0	12.9	6.5
137	Puerperal septicemia.....	6.8	6.3	3.7	6.5
152 ¹¹	Injuries at birth.....	6.6	5.0	2.8	2.1
43	Cancer of the breast.....	6.5	5.6	10.4	1.5
37	Syphilis.....	5.4	4.1	5.8	15.0 ¹⁰
126	Diseases of the prostate.....	3.4	2.6	4.2	0.7
132	Salpingitis and other diseases of ♀ genital organs.....	2.2	2.1	0.5	0.2
129	Uterine tumor (non-cancerous).....	1.8	1.8	0.8	0
134	Accidents of pregnancy.....	1.7	1.7	1.1	0.2
130	Other diseases of the uterus.....	1.6	1.7	0.4	0.4
136	Other accidents of labor.....	1.3	0.9	1.1	0.7
140	Following childbirth.....	1.1	1.5	0.1	—
131	Cysts and other tumors of ovary.....	1.0	1.3	0.8	0.2
135	Puerperal hemorrhage.....	1.0	1.0	1.3	1.7
125	Diseases of the urethra, urinary abscesses, etc.....	0.4	0.4	1.2	0.7
38	Gonococcus infection.....	0.3	0.1	0.2	0
128	Uterine hemorrhage (non-puerperal).....	0.2	0.3	0	0
127	Non-venereal diseases of ♂ genital organs.....	0.1	0.1	0.2	0
133	Non-puerperal diseases of breast (except cancer).....	0.1	0.1	0.1	0
139	Puerperal phlegmasia, etc.....	0.1	—	0.9	0
Totals.....		88.1	77.4	95.4	103.2

atrophy, marasmus, etc." Item 152, coming under the same general head of the International Classification has the general title "Other causes peculiar to early infancy (total)." This term contains two unnumbered subdivisions, the first being "Injuries at birth," and the other "Other causes peculiar to early infancy."

The question at once arises, why should these two items "Premature birth" and "Injuries at birth" be included with the primary and secondary sex organs, since it is obvious enough that the infants whose deaths are recorded under these heads in the vast majority of cases, if not all, have nothing whatever the matter with either their primary or secondary sex organs. The answer is,

¹⁰ Including soft chancre (syphilis 1.5, and soft chancre 13.5).

¹¹ In part. Cf. text here.

in general terms, that on any proper biological basis deaths coming under either of these two categories are not properly chargeable organically against the infant at all, but should be charged, on such a basis, against the mother. To go into further detail, it is apparent that when a premature birth occurs it is because the reproductive system of the mother, for some reason or other, did not rise to the demands of the situation of carrying the fetus to term. Premature birth, in short, results from a failure or breakdown in some particular of the maternal reproductive system. This failure may be caused in various ways, which do not here concern us. The essential feature from our present viewpoint is that the reproductive system of the mother does break down, and by so doing causes the death of an infant, and that death is recorded statistically under this title "Premature birth." The death organically is chargeable to the mother.

A considerable number of cases of premature birth are unquestionably due to placental defect and the placenta is a structure of fetal origin, so such deaths could not be properly charged to the mother. On the other hand, however, they would still stay in Table III, because the placenta may fairly be regarded as an organ intimately concerned in reproduction.

The same reasoning which applies to premature births, *mutatis mutandis*, applies to the item "Injuries at birth." An infant death recorded under this head means that some part of the reproductive mechanism of the mother, either structural or functional, failed of normal performance in the time of stress. Usually "injury at birth" means a contracted or malformed pelvis in the mother. But in any case the death is purely external and accidental from the standpoint of the infant. It is organically chargeable to a defect of the sex organs of the mother. The female pelvis, in respect of its conformation, is a secondary sex character.

A practical difficulty arose from the fact that in the São Paulo statistics items 151 and 152 are not subdivided.

In the case of the first of these, item 151, I have ventured to divide the total rate in roughly the same *proportion* between the two subdivisions as exists in the United States and England, namely $\frac{3}{5}$ to premature birth and $\frac{2}{5}$ to congenital debility, etc. While this is admittedly a hazardous proceeding, it seems to me less so than to omit entirely so important a rate, which seems to me the only other practical alternative. In the case of item 152 the total rate is so small (3.3) that no particular difference will be made whatever the basis of distribution used. Consequently, I have again divided it roughly on the basis of the American figures, calling $\frac{5}{8}$ of the total due to injuries at birth.

Table III also includes data which in the International Classification are distributed under three different general heads. First, "General diseases"; second, "Non-venereal diseases of the genito-urinary system and annexa"; and third, "Puerperal state." In the International List all cancers are included under "General diseases." We have taken out for inclusion here the several cancers of the primary and secondary sex organs, including item 42, "Cancer of the female genital organs," and item 43, "Cancer of the breast." Items 37 and 38, "Syphilis" and "Gonococcus infection," are also taken out of the class of "General diseases" of the International List. The immediate reason for including these diseases here is obvious, but particularly in relation to syphilis the point at once needs further discussion. As a cause of actual death, syphilis frequently acts through the central nervous system, and the question may fairly be raised why, in view of this fact, syphilis is not there included. The point well illustrates one of the fundamental difficulties in any organological classification of disease. In the case of syphilis, however, the difficulty in practise is not nearly so great as it is in theory. As a matter of fact, most of the deaths from the effect of syphilitic infection on the nervous system are recorded in vital statistics by reporting physicians and vital statis-

ticians as diseases of the nervous system. For example, it is perfectly certain that most of the deaths recorded as due to "locomotor ataxia" and "softening of the brain" are fundamentally syphilitic in origin. The rate included in Table III of 5.4 for the Registration Area of the United States in 1906-10 for deaths due to syphilis is far lower, as any clinician knows, than the number of deaths really attributable to syphilitic infection. These other deaths, due to syphilis, and not reported under that title, are reported under the organ which primarily breaks down and causes death, as, for example, the brain, and will in the present system of classification be included under the nervous system. After careful consideration it has seemed as fair and just as anything which could be done to put the residue of deaths specifically reported as due to syphilis under Table III, Primary and Secondary Sex Organs. The rate in any event is so small that whatever shift was made could not sensibly affect the general results to which we shall presently come.

The question may be asked as to why puerperal septicemia (item No. 137) is included here and not with the diseases of the circulatory system and blood on the same reasoning that general septicemia was put there. The cases seem to be essentially different. Puerperal septicemia arises fundamentally because of a failure of the reproductive system of the female to meet in a normal way the demands made upon it by the process of reproduction itself. In line with the general reasoning on which we are working in this classification, it would therefore seem that this cause of death belongs where it has been put here, with the primary and secondary sex organs. The same sort of reasoning applies to the other puerperal causes of death here included.

Item 125, "Diseases of the urethra, urinary abscesses, etc." is placed with the sex organs rather than with the excretory organs in Table IV, because, with very few exceptions, the deaths in this item are sequelæ of gonorrhea. Urinary abscesses are secondary usually to urethral

stricture, which in turn, except for an insignificant number of traumatic cases, is gonorrhreal in origin.

Regarding the wisdom of bringing together under one rubric the causes of death listed in Table IV on a biolog-

TABLE IV
KIDNEYS AND RELATED EXCRETORY ORGANS

No.	"Cause of Death" as per International Classification	Registration Area, U.S.A.		England and Wales 1914	Sao Paulo 1917
		1906-10	1901-05		
120	Bright's disease.....	87.4	87.4	37.0	41.2
119	Acute nephritis.....	10.1	9.6	5.4	29.4
138	Puerperal albuminuria and convulsions	3.4	2.8	1.7	1.7
124	Diseases of the bladder.....	3.1	4.3	3.3	1.3
121 & 122	Chyluria and other diseases of the kidneys.....	2.6	2.8	1.3	9.4
123	Calculi of the urinary passage.....	0.6	0.5	0.7	0.4
	Totals.....	107.2	107.4	49.4	83.4

ical basis, there would seem to be little doubt with a single exception. This does present a very difficult problem. Item 138, Puerperal albuminuria, is included here rather than with other puerperal diseases under the sex organs, or elsewhere, on the reasoning that the cause of death is finally the organic breakdown of the kidneys and not of the reproductive system, and bespeaks a fundamental organic weakness of the excretory system, which weakness is made to flare up into clinical nephritic trouble under the strain of pregnancy. Basically these toxemias are due to faulty maternal metabolism, of unknown origin, which can not in the present state of ignorance be properly charged against any particular organ or organ system. It, however, remains a fact that many women having organically sound excretory organs are able to weather even very severe metabolic storms of this sort near the end of pregnancy and survive. Others with organically weak excretory systems go down. In view of these facts it seems on the whole fairer to put these deaths here than against any other organ system.

The "rheumatisms" present another difficult ques-

tion. A precise and critical decision on the point of where these diseases belong in this present scheme of classification is impossible of attainment. Weighing all the evidence carefully, it seemed best to put chronic rheumatism and gout and acute articular rheumatism in Table V, under "Skeletal and muscular system," rather than here with the kidneys. Much at least of the fatal chronic rheumatism is really a chronic infective arthritis. Gout is a disease due to fundamental disturbances of general metabolism, but the statistical returns lump deaths from this cause with chronic rheumatism. The death rates from all of these diseases are, fortunately, so small that it makes no essential difference to the final synthetic result towards which we are working where they are placed.

TABLE V
SKELETAL AND MUSCULAR SYSTEM

No.	"Cause of Death" as per International Classification	Registration Area, U. S. A.		England and Wales 1914	São Paulo 1917
		1906-10	1901-05		
47	Acute articular rheumatism.....	5.4	5.2	5.6	2.6
146	Diseases of the bones.....	2.5	2.4	1.5	0.7
48	Chronic rheumatism and gout.....	2.2	3.6	5.4	0
32	Pott's disease.....	1.5	1.5	1.6	2.6
33	White swellings.....	0.7	0.7	0.9	0
147	Diseases of the joints.....	0.2	0.2	0.4	0
149	Other diseases of the organs of locomotion.....	0.1	0.1	0.1	0
36	Rickets.....	¹²	¹²	2.7	0.9
	Totals.....	12.6	13.7	18.2	6.8

Item 47, "Acute articular rheumatism," and the two tubercular affections, items 32 and 33 (Pott's disease and white swellings) are placed here because the essential lesion produced by the causative agents is in either the bones or the joints.

All of the rates in Table V are small, and any of the causes of death listed therein could be shifted to other rubrics without sensibly affecting any general result.

¹² Not separately tabulated.

In Table VI are included a number of causes of death beyond those which are included in general heading "V. Diseases of the digestive system" in the International

TABLE VI
ALIMENTARY TRACT AND ASSOCIATED ORGANS CONCERNED IN METABOLISM

No.	"Cause of Death" as per International Classification	Registration Area, U. S. A.		England and Wales 1914	São Paulo 1917
		1906-10	1901-05		
104	Diarrhea and enteritis (under 2)	96.2	89.0	63.6 ¹⁴	383.6
151 ¹³	Congenital debility, atrophy, marasmus	28.8	23.2	27.1	44.3
40	Cancer of the stomach and liver	28.3	24.7	36.5	28.1
1	Typhoid fever	25.6	32.0	4.6	14.4
103	Other diseases of stomach	16.8	17.7	10.9	1.3
105	Diarrhea and enteritis (2 and over)	16.7	20.2	—	49.9
113	Cirrhosis of the liver	14.3	14.4	11.2	12.2
50	Diabetes	13.7	11.5	12.2	5.4
109	Hernia and intestinal obstruction	12.9	13.0	10.9	3.0
71	Convulsions of infants	12.5	21.4	22.7	10.0
108	Appendicitis and typhlitis	11.2	11.0	7.1	3.5
41	Cancer of the peritoneum, intestines, rectum	8.8	7.1	21.3	4.1
14	Dysentery	6.5	8.6	0.7	9.6
117	Simple peritonitis	6.1	10.8	1.4	13.3
115	Other diseases of the liver	6.1	7.5	2.6	5.7
31	Abdominal tuberculosis	6.0	6.0	9.4	1.7
150 ¹³	Other congenital malformations	4.5	3.9	5.4	¹⁵
102	Ulcer of the stomach	3.6	2.9	5.5	3.5
110	Other diseases of intestines	2.8	2.9	1.4	5.4
114	Biliary calculi	2.8	2.2	2.3	0.4
39	Cancer of the buccal cavity	2.6	2.1	6.6	1.3
35	Disseminated tuberculosis	2.5	2.8	5.5	2.2
100	Diseases of the pharynx	1.6	1.4	2.1	0.4
13	Cholera nostras	1.0	1.4	0.1	0.2
99	Diseases of the mouth	0.7	0.7	1.5	0.4
59	Other chronic poisonings	0.5	0.5	0	0.2
118	Other diseases of the digestive system	0.5	0.3	0.6	1.1
111	Acute yellow atrophy of liver	0.4	0.4	0.2	0.4
101	Diseases of the esophagus	0.3	0.3	0.2	1.3
57	Chronic lead poisoning	0.2	0.3	0.2	0
26	Pellagra	0.2	0	0	0
49	Scurvy	0.1	0.1	0.1	0.2
106 &					
107	Parasites	0.1	0.1	0.1	6.3
112	Hydatid tumor of liver	¹⁶	¹⁶	0.1	0.2
27	Beriberi	¹⁷	¹⁷	0	0.2
12	Asiatic cholera	0	0	0	0
Totals		334.9	340.4	274.1	613.8

¹³ In part.

¹⁴ Diarrhea and enteritis, all ages.

¹⁵ See footnote to Table I.

¹⁶ Death rate less than 0.1 per 100,000.

¹⁷ Not separately tabulated for period named.

Classification. Of these causes which have been brought in from other parts of the International Classification the first which demands attention is the second on the list "Congenital debility, atrophy, marasmus." This is a part of item No. 151 of the International Classification. As already pointed out, that item includes "Premature birth," which has in the present classification been placed under "Primary and secondary sex organs" for reasons already stated, and "Congenital debility, atrophy, marasmus, etc.," which is the part included here. The reason for putting this portion of item 151 under the present heading is the practical one that clinical experience shows that the vast majority of the deaths of infants which are statistically recorded under this heading "Congenital debility, atrophy, and marasmus" are actually due to deficiencies, functional, structural, or both, in the alimentary tract. In probably more than 95 per cent. of all cases "Congenital debility" of an infant means that something is wrong with the alimentary tract in its immediate metabolic functions.

Item 50, "Diabetes," includes deaths from a disease which, while diagnosed from a disarrangement of the excretory function, is primarily an affection of the organs which have to do with the initial or early stages of metabolism (the liver, the pancreas, etc.). It therefore seems to belong properly in the classification where it is now placed rather than with the kidneys. In the International Classification it is included with "General diseases."

Item 71, "Convulsions of infants," is in the International Classification placed with "Diseases of the nervous system." It is transferred from that location to the present one in this classification because of the well-known clinical fact that the vast majority of deaths of infants recorded as due to convulsions are really due to profound disarrangements of the alimentary tract, which eventually lead to convulsions. Biologically, the fundamental breakdown in such cases is of the alimen-

tary tract and associated organs, and not of the brain or central nervous system.

The part of item 150 of the International Classification bearing the title "Other congenital malformations" needs some discussion in regard to its inclusion here. In other rubrics of the present classification we have taken account of hydrocephalus and congenital malformation of the heart, both of which come under the general heading "X. Malformations" of the International Classification. The only other rubric under that heading in the International Classification is the one here under discussion "Other congenital malformations." It is, of course, impossible to say in detail what these other congenital malformations are. It seems fair, however, to assume from general knowledge that after hydrocephalus and congenital malformations of the heart are deleted, the great majority of the remaining congenital malformations will relate directly to the alimentary tract or some of its associated organs. Quantitative proof that this is the case is not forthcoming for obvious reasons. The placing of this item here is simply on the basis of the best information it is possible to get from those most familiar with congenital malformations in infants. There is undoubtedly some error inherent in placing this title here, but the net effect of such error must be insignificant for the reason that the death rate under this rubric is very small in total, as will be seen from the table, and furthermore, as has already been stated, it is certain on general grounds that the vast bulk of deaths included here must be due to malformations of the alimentary tract or its associated organs.

Items No. 31 and 35 (Abdominal tuberculosis, and disseminated tuberculosis) are placed here, because, while these titles are somewhat indefinite, it is quite certain that the major portion of the deaths recorded by health officers under these terms are due to tubercular affections of the alimentary tract.

Items 57, 59, 26, 27, and 49 (chronic lead poisoning,

other chronic poisonings, pellagra, beriberi, and scurvy) present an interesting problem. The question is whether they should go here or with external causes in Table X. It can be argued that on the one hand, the poisonings are due simply to the ingestion of a deleterious agent and death has no biological basis any more than if a person is struck by an automobile, and, on the other hand, that deaths from the diseases like pellagra and beriberi again simply arise from the fact that the victim lacked a proper diet. But the case is not so simple as this argument would imply. Not all workers in paint factories, nor all inmates of insane asylums or prisons die from these causes. Some survive. And it is reasonable, it seems to me, to suppose that in many cases at least the determining factor in the survival is the relative organic soundness or "strength" of the organs primarily concerned in metabolism. On this basis, this group of causes of death is included in Table VI. Fortunately, they are all insignificant contributions to the total death rate.

Regarding the other items in Table VI, taken from the "General disease" class of the International Classification, there is no need for discussion because it is sufficiently evident that on a biological classification they belong here rather than with any other organ group.

The enormous excess of the Sao Paulo death rate for the total of the items in Table VI as compared with the Registration Area of the United States and England and Wales is noteworthy. Examination of the data will show that it arises almost entirely from the excessive death rate in Sao Paulo from diarrhea and enteritis (under 2).

In the main the causes of death included in Table VII in addition to those which appear in class II, "Diseases of the nervous system and of the organs of special sense" of the International Classification, so obviously belong here as to require no special discussion. Two, however, call for comment. Of these the most important is suicide. In the International Classification suicides are placed under "XIII. External causes," a singularly inept loca-

TABLE VII
NERVOUS SYSTEM AND SENSE ORGANS

No.	"Cause of Death" as per International Classification	Registration Area, U.S.A.		England and Wales 1914	São Paulo 1917
		1906-10	1901-05		
64	Cerebral hemorrhage and apoplexy	71.7	69.6	65.3	32.9
61	Meningitis (total)	19.4	31.7	11.5	43.1
66	Paralysis without specified cause	16.1	20.1	7.3	2.6
	Suicide (total)	16.0	13.9	10.0	12.9
30	Tuberculous meningitis	9.1	8.9	12.6	0
56	Alcoholism	5.8	6.1	1.8	2.8
63	Other diseases of the spinal cord	5.8	4.9	7.5	4.4
73 &					
74	Neuralgia, neuritis and other diseases of the nervous system	5.5	6.9	7.0	2.0
67	General paralysis of the insane	5.5	6.8	6.1	3.0
69	Epilepsy	4.2	4.4	7.6	4.8
68	Other forms of mental alienation	3.6	3.6	2.7	0.7
24	Tetanus	2.7	3.5	0.5	4.6
62	Locomotor ataxia	2.6	2.4	1.9	0.2
65	Softening of the brain	2.5	3.7	3.9	0.7
76	Diseases of the ears	1.6	1.3	3.3	0
150 ¹⁸	Hydrocephalus	1.4	1.6	1.0	¹⁹
60	Encephalitis	1.1	1.9	0.9	1.3
70	Convulsions (non-puerperal)	0.5	1.1	0.3	1.7
72	Chorea	0.2	0.3	0.5	0
23	Rabies	0.2	0.1	0	0.7
75	Diseases of the eye and annexa	0.1	0.1	0.2	0
17	Leprosy	20	20	0	5.9
	Totals	175.6	192.9	151.9	124.3

tion biologically. The immediate motivation of a suicidal death is surely internal. A searching biological analysis of the phenomenon of suicide has yet to be made, but certain of its biological relations are clear enough. In the broadest terms people commit suicide because their higher cerebral mechanism breaks down under the stresses of the world in which they live, and fails to continue its normal functioning. One of the deepest rooted instincts of the individual among all living things, from lowest to highest, is the instinct for the preservation of the individual life. The only instinct which transcends it, and that only in comparatively few cases in lower animals, is the instinct of reproduction. But the phenom-

¹⁸ In part.

¹⁹ See footnote Table I.

²⁰ Less than 0.1 per 100,000.

enon of suicide in man marks the complete and total inhibition of this instinct of self-preservation. Suicide is always an act in some degree mentally deliberated before its performance. A constitutionally and hygienically sound mentality weathers the environmental storm which suggests suicide. On the basis of this reasoning suicide death rate is put in Table VII.

Item 56, "Alcoholism," is included here because fundamentally deaths so returned would seem to be more truly chargeable against the central nervous system than to any other organ system. This opinion is founded on such results as those of Barrington and Pearson,²¹ who conclude, after a careful analysis of data regarding extreme and chronic inebriates, that "there appears for constant age little relation between alcoholism and physical fitness," while between mental defect (and poor education) and alcoholism there is a sensible relation. "We consider it probable . . . that the alcoholism is not due to the poor education, nor is it to any marked extent productive of the mental defect, but the want of will-power and self-control associated with the mental defectiveness is itself the antecedent of the poor education and of the alcoholism."

The other cause of death needing special comment here is leprosy. I am informed by my friend, Dr. G. H. de Paula Souza, who has had unusual opportunities to know leprosy in all its clinical manifestations, that when this disease becomes fatal it is the nervous system which disintegrates and leads to death.

The first five items in Table 8 are affections of the skin about which there can be no doubt respecting the correctness of their inclusion here. The last four items, smallpox, anthrax, mycoses and glanders are all diseases with very low death rates at the present time. Biologically, they represent diseases which either gain entrance through the skin, or in which the principal lesions are of

²¹ Barrington, A., and Pearson, K., "A Preliminary Study of Extreme Alcoholism in Adults," *Eugenics Lab. Mem.*, XIV, 1910.

TABLE VIII

THE SKIN

No.	"Cause of Death" as per International Classification	Registration Area, U. S. A.		England and Wales 1914	São Paulo 1917
		1906-10	1901-05		
18	Erysipelas.....	4.2	4.5	3.1	1.3
44	Cancer of the skin.....	2.7	2.3	2.6	1.5
144	Acute abscess.....	1.1	1.4	2.1	0.7
145	Other diseases of the skin.....	1.0	1.0	3.4	2.4
143	Furuncle.....	0.5	0.5	0.7	0.2
5	Smallpox.....	0.2	3.4	0	0.7
22	Anthrax.....	0.2	0.1	0	0
25	Mycoses.....	0.2	—	0.1	1.1
21	Glanders.....	—	0.1	0	0
Totals.....		10.1	13.3	12.0	7.9

the skin. It therefore appears that on the present scheme of classification they may best be put here.

There is no doubt whatever that the three diseases of Table IX belong biologically with the endocrinial system.

In the foregoing tables have been included all statistically recognized causes of death which it is now possible to classify on an organological basis, and which have a

TABLE IX
ENDOCRINAL SYSTEM

No.	"Cause of Death" as per International Classification	Registration Area, U.S.A.		England and Wales 1914	São Paulo 1917
		1906-10	1901-05		
51	Exophthalmic goiter.....	1.1	0.7	1.3	0.4
52	Addison's disease.....	0.4	0.5	0.6	0.7
88	Diseases of the thyroid body.....	0.4	0.3	0.8	0
Totals.....		1.9	1.5	2.7	1.1

significant death rate. The residue comprises in general three categories (*a*) accidental and homicidal deaths; (*b*) senility; and (*c*) deaths from a variety of causes which are statistically lumped together and can not be disentangled. Accidental and homicidal deaths find no place in a biological classification of mortality. A man organically sound in every respect may be instantly killed by being struck by a railroad train or an automo-

bile. The best possible case that could be made out for a biological factor in such deaths would be that contributory carelessness or negligence, which is a factor in some portion of accidental deaths, bespeaks a small but definite organic mental inferiority or weakness, and that, therefore, accidental deaths should be charged against the nervous system. This, however, is obviously not sound. For in the first place in many accidents there is no factor of contributory negligence in fact, and in the second place in those cases where such negligence can fairly be alleged its degree or significance is undeterminable and in many cases surely slight.

Senility as a cause of death is not further classifiable on an organological basis. A death really due to old age, in the sense of Metchnikoff, represents, from the point of view of the present discussion, a breaking down or wearing out of all the organ systems of the body contemporaneously. In a strict sense this probably never, or at best extremely rarely, happens. But physicians and registrars of mortality still return a certain number of deaths as due to "senility." Under the circumstances it is not possible to go behind such returns biologically.

TABLE X
ALL OTHER CAUSES

No.	"Cause of Death" as per International Classification	Registration Area, U. S. A.		England and Wales 1914	São Paulo 1917
		1906-10	1901-05		
187, 188 &	All external causes (except suicide)	91.9	87.8	26.1	36.4
189	Ill-defined diseases.	29.4	47.8	7.3	36.3
154	Senility.	29.0	41.0	81.5	11.1
45	Cancer of other organs or of organs not specified.	12.9	16.1	16.6	17.9
152 ²²	Other causes peculiar to early infancy	3.4	2.6	5.1	3.3
34	Tuberculosis of other organs.	2.1	2.0	1.6	0.2
46	Other tumors (female genital organs excepted)	1.0	1.5	0.5	0.9
55	Other general diseases.	1.0	0.5	1.5	3.5
153	Lack of care.	0.3	12.3	0.6	0
19	Other epidemic diseases.	0.3	0.2	0.6	0.2
	Totals.	171.3	211.9	141.4	109.8

²² Less than 0.1 per 100,000.

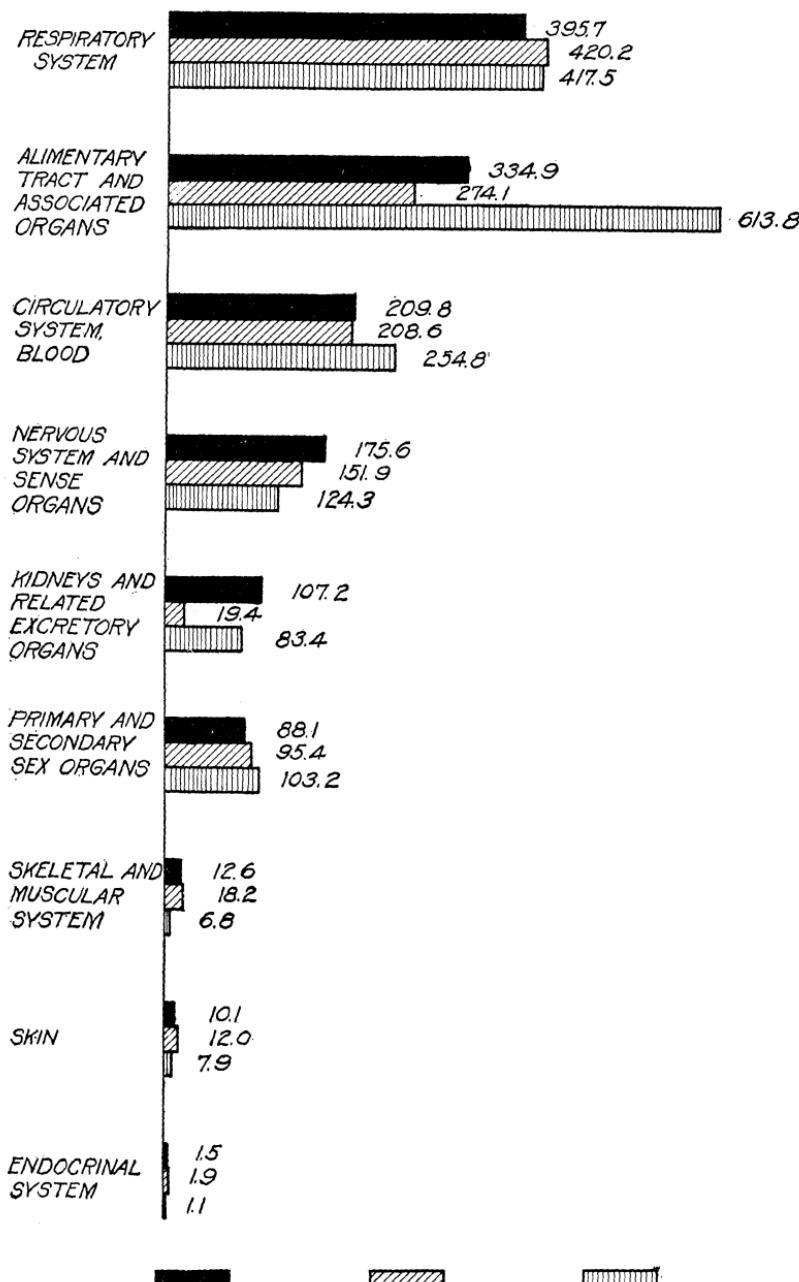
The second line of Table X, "Ill-defined diseases," furnishes a striking commentary on the relative efficiency of the medical profession in the United States and England in respect of the reporting of the causes of death. Only about one fourth as many deaths appear in the English vital statistics as due to ill-defined and unknown causes as in the United States figures. Happily, the conditions in this regard are constantly improving in the Registration Area of the United States, due to the well-conceived and untiring efforts of the officials in charge of vital statistics in the Bureau of the Census. They deserve the warmest gratitude of every American vital statistician for the improvements in registration they have brought about.

IV

Having now arranged, so far as possible, all statistically recognized causes of death in a biological classification, we may turn to an examination of the results which such an arrangement shows. In Table XI the totals of Tables I to IX, inclusive, are arranged in descending order of magnitude. The results are shown graphically in Fig. 1.

TABLE XI
SHOWING THE RELATIVE IMPORTANCE OF DIFFERENT ORGAN SYSTEMS IN
HUMAN MORTALITY

Group No.	Organ System	Death Rates per 100,000			
		Registration Area, U. S. A.		England and Wales 1914	São Paulo 1917
		1906-10	1901-05		
II	Respiratory system.....	395.7	460.5	420.2	417.5
VI	Alimentary tract and associated organs	334.9	340.4	274.1	613.8
I	Circulatory system, blood.....	209.8	196.8	208.6	254.8
VII	Nervous system and sense organs.....	175.6	192.9	151.9	124.3
IV	Kidneys and related excretory organs.....	107.2	107.4	19.4	83.4
III	Primary and secondary sex organs.....	88.1	77.4	95.4	103.2
V	Skeletal and muscular system.....	12.6	13.7	18.2	6.8
VIII	Skin.....	10.1	13.3	12.0	7.9
IX	Endocrinial system.....	1.5	1.2	1.9	1.1
	Total death rate classifiable on a biological basis.....	1,335.5	1,403.6	1,201.7	1,612.8
X	All other causes of death.....	171.3	211.9	141.4	109.8



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FIG. 1. Diagram showing the relative importance of the different organ systems of the body in human mortality.

From Table XI and the diagram a number of noteworthy points can be made out.

1. In the United States, during the decade covered, more deaths resulted from the breakdown of the respiratory system than from the failure of any other organ system of the body. The same thing is true of England and Wales. In São Paulo the alimentary tract takes first position, with the respiratory system a rather close second. The tremendous death rate in São Paulo chargeable to the alimentary tract is chiefly due, as Table VI clearly shows, to the relatively enormous number of deaths of infants under two from diarrhea and enteritis. Nothing approaching such a rate for this category as São Paulo shows is known in this country or England.

2. In all three localities studied the respiratory system and the alimentary tract together account for rather more than half of all the deaths biologically classifiable. These are the two organ systems which, while physically internal, come in contact directly at their surfaces with environmental entities (water, food, and air) with all their bacterial contamination. The only other organ system directly exposed to the environment is the skin. The alimentary canal and the lungs are, of course, in effect invaginated *surfaces* of the body. The mucous membranes which line them are far less resistant to environmental stresses, both physical and chemical, than is the skin with its protecting layers of stratified epithelium.

3. The organs concerned with the blood and its circulation stand third in importance in the mortality list. Biologically the blood, through its immunological mechanism, constitutes the second line of defense which the body has against noxious invaders. The first line is the resistance of the outer cells of the skin and the lining epithelium of alimentary tract, lungs, and sexual and excretory organs. When invading organisms pass or break down these first two lines of defense the battle is then with the home guard, the cells of the organ system which, like the industrial workers of a commonwealth, keep the body

going as a whole functioning mechanism. Naturally it would be expected that the casualties would be far heavier in the first two defense lines (respiratory and alimentary systems, and blood and circulation) than in the home guard. Death rates when biologically classified bear out this expectation.

4. It is at first thought somewhat surprising that the breakdown of the nervous system is responsible for more deaths than that of the excretory system. When one bears in mind, however, the relative complexity of the two pieces of machinery, it is perceived that the relative position of the two in responsibility for mortality is what might reasonably be expected.

5. In the United States the kidneys and related excretory organs are responsible for more deaths than the sex organs. This relation is reversed in England and Wales and in Sao Paulo. A return to Table III shows that this difference is mainly due, in the case of England, to two factors, premature birth and cancer. In Sao Paulo it is due to premature birth and syphilis. The higher premature birth rate for these two localities as compared with the United States might conceivably be explained in either of two ways. It might mean better obstetrics here than in the other localities, or it might mean that the women of this country as a class are somewhat superior physiologically in the matter of reproduction, when they do reproduce. The first suggestion seems definitely more improbable than the second. The higher apparent syphilis rate of Sao Paulo probably means nothing more than better reporting, a less prudish disinclination to report syphilis as a cause of death in Sao Paulo than in the other two countries. It is by no means beyond the bounds of possibility that if all deaths really due to syphilis and gonorrhea were actually reported as such, the rate for the sex organs would be decidedly higher than for the excretory organs in all countries.

6. The last three organ systems in the table, skeletal and muscular system, skin and endocrinial organs, are

responsible for so few deaths relatively as not to be of serious moment.

7. In a broad sense the efforts of public health and hygiene have been directed against the afflictions comprised in the first two items in the table, respiratory system and alimentary tract. The figures in the first two columns for the two five-year periods in the United States indicate roughly the rate of progress such measures are making, looking at the matter from a broad biological standpoint. In reference to the respiratory system there was a decline of 14 per cent. in the death rate between the two periods. This is substantial. It is practically all accounted for in phthisis, lobar pneumonia and bronchitis. For the alimentary tract the case is not so good—indeed, far worse. Between the two periods the death rate from this cause group fell only 1.8 per cent. Reference to Table VI shows how all the gain made in typhoid fever was a great deal more than offset by diarrhea and enteritis (under two), congenital debility and cancer. Child welfare, both prenatal and postnatal, seems by long odds the most hopeful direction in which public health activities can expect at the present time substantially to reduce the general death rate. This is a matter fundamentally of education. Ignorant and stupid people must be taught, gently if possible, forcibly if necessary, how to take care of a baby both before and after it is born. It seems at present unlikely that mundane law will regard feeding a two months old baby cucumber, or dispensing milk reeking with deadly poison makers, as activities accessory to first-degree murder. But we are moving in that direction under the enthusiastic and capable leadership of the Federal Children's Bureau. And there is this further comfort, that if that final Judgment Seat, before which so many believe we must all eventually appear, dispenses that even-handed justice which in decency it must, many of our most prominent citizens who in the financial interests of themselves or their class block every move towards better sewage disposal, water and milk

supply and the like, or force pregnant women to slave over washtub or sewing bench that they may live, will find themselves irrevocably indicted for the wanton and wilful slaughter of innocent babies.

V

We come now to the final stage in this study. Having arranged so far as possible all causes of death on an organological base, it occurred to me to go one step further back and combine them under the headings of the primary germ layers from which the several organs developed embryologically. To do this is a task of considerable difficulty. It raises intricate, and in some cases still unsettled, questions of embryology. Furthermore, the original statistical rubrics under which the data are compiled by registrars of vital statistics were never planned with such an object as this in mind. Still the thing seemed worth trying because of the evolutionary interest which would attach to the result, even though it were somewhat crude and in respect of minor and insignificant details open to captious criticism.

In Tables XII and XIII the death rates of Tables I to IX are subsumed under the three captions, ectoderm, mesoderm and endoderm, according as the organ concerned developed from one or the other of these germ layers. It will be necessary, however, before presenting the tables, to set forth in detail how the figures they contain were made up.

A. Ectoderm.—Under this head were placed first, in making up Table XII, the totals of Table VII (the nervous system and sense organs), and Table VIII (the skin). To the sum obtained by adding these totals together was added (a) item 39 (cancer of the buccal cavity) from Table VI, on the ground that the lining of the buccal cavity is ectodermal in origin; (b) 0.30 of the rates under item 41 (cancer of the peritoneum, intestines and rectum). The point here was that the lining epithelium of the rectum is derived from ectoderm. The cancer rates for

these three embryologically different organs, rectum, intestines and peritoneum are arbitrarily lumped together by the registrars of vital statistics. It is necessary for present purposes to unscramble the figures with as little arbitrariness as possible. Data (admittedly rather meager) given by Hoffman²³ (pp. 116-121) from the New York State investigation indicate that in a lumped total of cancer of the peritoneum, intestines and rectum, the fractions incident upon each of the organs are about 0.04 for peritoneum, 0.30 for rectum, and 0.66 for intestines. As these figures are much less arbitrary than a mere guess, I have adopted them. It should be remembered that in the final result it makes little difference what fraction is adopted, because the total rate under item 41 is so small. A remarkable thing which comes out when the lumped figures for cancer of peritoneum, intestines and rectum are subdivided in the above-named proportions, is the similarity, amounting practically to identity, in the death rates in all four times and places studied, from cancer of the buccal cavity and cancer of the rectum. The figures are as follows:

	U. S. A.		England and Wales	São Paulo
	1906-10	1901-05		
Cancer of buccal cavity.....	2.6	2.1	6.6	1.3
Cancer of rectum (calculated).....	2.6	2.1	6.4	1.2

This identity can hardly be accidental, since it occurs in all three different localities with quite different cancer rates in each. It indicates that the fundamental embryological likeness between buccal cavity and rectum is accurately reflected in their neoplastic pathology, provided it can be safely assumed the portion of the rectum in which cancers preponderantly occur is ectodermic. This appears to be the fact. (c) Item 86 (diseases of the nasal fossæ) is added, because the lining membrane of the nose is ectodermal in origin.

²³ Hoffman, F. L., "The Mortality from Cancer throughout the World," Newark, 1915.

B. Mesoderm.—Here the figures of Table XII were reached by the following process. First, the totals of Table I (circulatory system), Table III (sex organs), and Table IV (kidneys), were added together, these being obviously in general mesodermic. From the total so obtained was *subtracted* item 124 of Table IV (diseases of the bladder) since the lining epithelium, the most vulnerable part pathologically, is endodermic in origin. For the same reason item 125 of Table IV (diseases of the urethra) was next subtracted. To the result so obtained was *added* (a) the total of Table V (skeletal system) and item 52 (Addison's disease) from Table IX, these representing organs mesodermic in origin; (b) 0.04 of the rate under item 41 of Table VI (cancer of peritoneum); (c) item 117 (simple peritonitis); (d) item 93 (pleurisy). The pleura and peritoneum are mesodermic structures and therefore clearly belong here. The final totals reached after the above described process are those which appear under "Mesoderm" in Table XII.

Up to this point in the argument it has been assumed, without discussion, that all the items in Table VII (the nervous system and sense organs) go with the ectoderm. There is, however, another point of view possible here, which may be stated in the following way. Cerebral hemorrhage and apoplexy (item 64) and softening of the brain (item 65) are brain conditions brought about by a precedent functional breakdown of a part of the vascular system, namely the terminal arteries of the brain. Cerebral hemorrhage is due to the rupture of an artery or arteries in the brain, and may in and of itself be a sufficient cause of death, just as would be a hemorrhage due to rupture of an artery in any other part of the body. So far as anything now known can tell us, this fatal accident is as likely as not to occur in a brain of which the nerve cells (of ectodermic origin) are perfectly sound organically. Should such a death be charged against the ectoderm? The case is at least open to question.

It might at first be supposed that the same argument would justify the placing of cerebral hemorrhage with the circulatory system in the primary organological classification, but this does not seem to be warranted. From an organological point of view the brain must be considered as a *whole organ*, the machinery of its vascular supply being included as well as its proper nervous components. So in this respect cerebral hemorrhage properly belongs where it is placed in Table VII, with the nervous system.

But the case is different from the embryological viewpoint. Suppose it be granted for the moment that there are specific differences between tissues originating from the different germ layers in respect of their likelihood to break down functionally under strain. Then clearly the tendency to any such specificity would be obscured if we charged to ectoderm the breakdown of any organ primarily originating from that germ layer, but where in fact the initial cause of the functional stopping of the proper ectodermic tissue was the prior breakdown of a part of the organ which was mesodermic in origin. This is precisely the condition of affairs relative to the pathology of cerebral hemorrhage.

Again, softening of the brain is really a necrosis of brain tissue resulting from a cutting off of its nourishment by stoppage of the circulation, which in turn may be due to arthritis, thrombosis, embolism or pressure. The same reasoning applies here as in the case of cerebral hemorrhage.

In so complicated a matter as the distribution of causes of death to their embryological base probably the most that can ever be hoped for, having regard to the enormous complications of structural development, is to get limiting values, within the range comprehended by which, the true fact may be reasonably supposed to lie. To this end Table XIII has been constructed. It with Table XII gives lower and upper limiting values for death rates chargeable to ectoderm and mesoderm. Table XIII is

made up in the same way as Table XII except that in the former items 64 and 65 are transferred from ectoderm to mesoderm. So far as I have been able to think the matter through it does not appear that the same complication may fairly be considered to arise in connection with the embryological assignment of any other "cause of death."

TABLE XII

SHOWING THE RELATIVE INFLUENCE OF THE PRIMARY GERM LAYERS IN HUMAN MORTALITY

(Items 64 and 65 charged to ectoderm)

Locality	Death Rate per 100,000 Due to Functional Breakdown of Organs Embryologically Developing from					
	Ectoderm	%	Mesoderm	%	Endoderm	%
U. S. Registration Area, 1906-10.....	191.1	14.3	425.2	31.8	719.6	53.9
U. S. Registration Area, 1901-05.....	210.6	15.0	407.1	29.0	786.2	56.0
England and Wales, 1914	177.1	14.4	374.0	30.3	681.5	55.3
Sao Paulo, 1917.....	134.9	8.4	468.0	29.0	1,009.9	62.6

C. Endoderm.—The process of getting the figures here was to add together first the totals of Tables II and VI (respiratory system and alimentary tract) the organs represented being mainly endodermal in origin. Then there were *subtracted* from this total the following: (a) items 39 (cancer of the buccal cavity) and 0.34 of item 41 (cancer of the peritoneum, intestines, and rectum), leaving 0.66 of this latter item here for cancer of intestines; (b) items 117 (simple peritonitis) and 93 (pleurisy); (c) item 86 (diseases of the nasal fossæ). All of these items subtracted have been already placed with either ectoderm or mesoderm. Finally, there were *added* items 124 and 125 (diseases of the bladder and of the urethra) which were taken from the mesoderm for reasons already stated under that heading. Also there were added items 51 and 88 from Table IX (exophthalmic goiter and diseases of the thyroid body), because the thyroid arises from the epithelium lining the inner branchial furrows. The re-

sult finally obtained by the process described is that which appears in Tables XII and XIII under "endoderm."

TABLE XIII

SHOWING THE RELATIVE INFLUENCE OF THE PRIMARY GERM LAYERS IN HUMAN MORTALITY
(Items 64 and 65 charged to mesoderm)

Locality	Death Rate per 10,000 Due to Functional Breakdown of Organs Embryologically Developing from					
	Ectoderm	%	Mesoderm	%	Endoderm	%
U. S. Registration Area, 1906-10.....	116.9	8.7	499.4	37.4	719.6	53.9
U. S. Registration Area, 1901-05.....	137.3	9.8	480.4	34.2	786.2	56.0
England and Wales, 1914	107.9	8.7	443.2	36.0	681.5	55.3
Sao Paulo, 1917.....	101.3	6.3	501.6	31.1	1,009.9	62.6

The data of Tables XII and XIII are shown graphically in percentage form in Fig. 2.

The final results shown in Tables XII and XIII lead at once to a generalization of considerable interest and significance to the evolutionist. The figures show that in man, the highest product of organic evolution, about 57 per cent. of all the biologically classifiable deaths result from a breakdown and failure further to function of organs arising from the endoderm in their embryological development, while but from 8 per cent. to 13 per cent. can be regarded as a result of breakdown of organ systems arising from the ectoderm. The remaining 30 to 35 per cent. of the mortality results from failure of mesodermic organs. Taking a general view of comparative anatomy and embryology it is evident that in the evolutionary history through which man and the higher vertebrates have passed it is the ectoderm which has been most widely differentiated from its primitive condition, to the validity of which statement the central nervous system furnishes the most potent evidence. The endoderm has been least differentiated in the process of evolution, while the mesoderm occupies an intermediate position in this respect. An elaborate array of evidence might be presented on these points, but to do so would be

supererogation. It would amount simply to repeating any standard treatise on the comparative anatomy of the vertebrates, a branch of biological literature which one



U.S. REGISTRATION AREA 1906-10



ENGLAND AND WALES 1914



SAO PAULO 1917



ENDODERM



MESODERM



ECTODERM

FIG. 2. Diagram showing the percentages of biologically classifiable human mortality resulting from breakdown of organs developing from the different germ layers. Upper bar of pair gives upper limit of mortality chargeable to ectoderm: lower bar gives lower limit of mortality chargeable to endoderm.

may fairly assume that the readers of this paper are acquainted with, at least in general terms.

Degree of differentiation of organs in evolution implies degree of adaptation to environment. The writings of Darwin and Spencer, and in current times of Henry Fairfield Osborn, have demonstrated this point beyond question. From the present point of view we see that that germ layer, the endoderm, which has evolved or become differentiated least in the process of evolution is

least able to meet successfully the vicissitudes of the environment. The ectoderm has changed most in the course of evolution. The process of differentiation which has produced the central nervous system of man had as a concomitant the differentiation of a protective mechanism, the skull and vertebral column, which very well keeps the delicate and highly organized central nervous system away from direct contact with the environment. The skin exhibits many differentiations of a highly adaptive nature to resist environmental difficulties. It is then not surprising that the organ systems developed from the ectoderm break down and lead to death less frequently than any other.

The figures of Tables XII and XIII make it clear that man's greatest enemy is his own endoderm. Evolutionally speaking, it is a very old-fashioned and out-of-date ancestral relic, which causes him an infinity of trouble. Practically, all public health activities are directed towards overcoming the difficulties which arise because man carries about this antediluvian sort of endoderm. We endeavor to modify the environment, and soften its asperities down to the point where our own inefficient endodermal mechanism can cope with them, by such methods as preventing bacterial contamination of water, food and the like, warming the air we breathe, etc. But our ectoderm requires no such extensive amelioration of the environment. There are at most only a very few if any germs which can gain entrance to the body through the normal, healthy, unbroken skin. We do, to be sure, wear clothes. But it is at least a debatable question whether upon many parts of the earth's surface we should not be better off without them from the point of view of health.

These tables indicate further in another manner how important are the fundamental embryological factors in determining the mortality of man. Of the three localities compared, England and the United States may fairly be regarded as much more advanced in matters of public

health and sanitation than Sao Paulo. This fact is reflected with perfect precision and justice in the relative proportion of the death rates from endoderm and ectoderm. In the United States and England about 55 per cent. of the classifiable deaths are chargeable to endoderm and about 9 to 14.5 per cent. to ectoderm. In Sao Paulo 62.6 per cent. fall with the endoderm, and but 6.3 to 8.4 per cent. with the ectoderm. Since, as we have already shown, public health measures can and do affect practically only the death rate chargeable to endoderm this result which is actually obtained is precisely that which would be expected.

Finally, it seems to me that the results of this study add one more link to the already strong chain of evidence which indicates the highly important part played by innate constitutional biological factors as contrasted with environmental factors in the determination of the observed rates of human mortality. Here we have grouped human mortality into broad classes which rest upon a strictly biological basis. When this is done it is found that the proportionate subdivision of the mortality is strikingly similar in such widely dissimilar environments as the United States, England and Southern Brazil. It is inconceivable that such congruent results would appear if the environment were the predominant factor in human mortality. This conclusion does not overlook the fact that in some diseases the environment, in a broad sense, is unquestionably the factor of greatest importance. Nor does it imply that every effort should not be used to measure in every case the precise relative influence of constitution or heredity as compared with environment in the natural history of particular diseases. This constitutes one of the most pressing and difficult problems of medical science.

VI

By way of summary it may be said that the purpose of this paper is to rearrange the rates of human mortality

as given in official reports of vital statistics, under the code known as the International Classification, into another classification upon a biological basis. The basis taken is organological, each "cause of death" is charged against that organ or organ system, the functional breakdown of which is fundamentally responsible for the death. It is found that from 85 to 90 per cent. of all statistically recognized causes of death can be subsumed under such a biological classification. It is found when this is done that the order of significance of the different organ systems in responsibility for human mortality is in general that of the following list, the arrangement being in descending order:

1. Respiratory system.
2. Alimentary tract and associated organs.
3. Circulatory system and blood.
4. Nervous system and sense organs.
5. Kidneys and related excretory organs.
6. Primary and secondary sex organs.
7. Skeletal and muscular system.
8. Skin.
9. Endocrinal system.

The arrangement differs slightly for different countries. If the further step is taken of referring the different organs and organ systems to the primary germ layers from which they embryologically developed, it is found that the death rates chargeable to organs of (*a*) ectodermic, (*b*) mesodermic and (*c*) endodermic origin stand to each other somewhere between the ratios of 1 to 2.3 to 4.4 and 1 to 4.4 to 7. The evolutionary and public health significance of these results is discussed at some length.